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Selecting Analytic Approaches for Decision Situations
(Revised Edition)

VOLUME I: An Overview of the Methodology

R.V. Brown
J.W. Ulvila

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SELECTING ANALYTIC APPROACHES FOR DECISION SITUATIONS
(Revised Edition)

VOLUME I: AN OVERVIEW OF THE METHODOLOGY

by

R.V. Brown
J.W. Ulvila

Sponsored by

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The three volumes of this report present a conceptual framework within which experienced decision analysts can derive generalizations that match analytic techniques to decision situations and communicate those generalizations to decision makers and inexperienced analysts. The framework consists of a three-way taxonomy: decision situations, analytic options, and performance measures.

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The first component is a "situation taxonomy," listing about one hundred dimensions of a situation that might be relevant to a particular analytic choice. These dimensions include: the stakes involved in a decision; the reaction time available; and the clarity with which options, probable consequences, and values are perceived.

The second component is an "analysis taxonomy," according to which about one hundred decision-analytic choices can be located in an "analytic option space." Dimensions of the analytic taxonomy include: how much decision analysis is undertaken, how it is used, what type of model structure is involved, and what technique for probability assessment or consequence evaluation is employed.

The third component is a "performance measure taxonomy," listing about thirty measures of effectiveness which can characterize the analytic options. The same taxonomy can also be used to describe a situation by expressing the relative importance of the performance measures in the situation. Performance measure dimensions include: enhanced logical reasoning, cost, speed, convenience, and facilitated communication. This component serves as a mediating factor, implicit or explicit, in matching analysis to situation.

In this research effort, we have attempted to identify a few important and plausible matching generalizations based on the experience of practicing decision analysts. A few analytic options were selected to represent thousands of possibilities and to facilitate generalizations about when they should be exercised in the form of a taxonomy matching. A U.S. decision on whether to export high-technology items to the Soviet Bloc is analyzed by using the taxonomic matching framework. Other illustrative material is also used throughout the report.

SUMMARY

Decision makers and decision analysis practitioners are both faced with problems of determining what type of analysis, if any, to apply to a given decision situation. The standard approach in such cases has been for the decision maker or analyst to evaluate, case by case, any special features of the situation and for him to apply informal experience and judgment, reflecting his perception of the state-of-the-art of decision analysis, to determine the appropriate approach for the situation.

The ultimate objective of this project is to improve on this method by providing decision makers with the means to identify those formal decision analytic techniques that are best suited for different decision situations. Two important sub-goals contribute to this goal. First, an easy, efficient way must be found to allow a decision maker to draw on the accumulated wisdom in the heads of experienced decision analysis practitioners and in the literature on applied decision analysis. Second, a conceptual framework must be developed to help decision analysis practitioners to derive rules that relate the proper analysis techniques to situations.

One way to meet the first sub-goal is to develop a systematic language for describing decision situations and analytic options so that experienced decision analysis practioners can more easily communicate their suggested guidance to decision makers. This report follows this path by presenting rather complete taxonomies that classify decision situations and analytic options.

The situation taxonomy lists about one hundred dimensions of a situation that might be relevant to a particular analytic choice. Such dimensions are chosen according to their familiarity to decision makers so that they can easily and completely classify any decision situation as an unambiguous "point in situation space." These dimensions include: the stakes involved in a decision; the reaction time available; and the clarity with which options, probable consequences, and values are perceived.

The "analysis taxonomy" lists about one hundred decision-analytic techniques that could be used on decision problems. These techniques, the dimensions of the analysis taxonomy, are defined such that a decision analysis expert can identify each complete analysis as a "point in analytic option space." The dimensions of the analysis taxonomy include: the amount of decision analysis undertaken, the way this analysis is used, the type of model structure involved, and the techniques for probability assessment or consequence evaluation employed.

To address the second sub-goal, facilitating the derivation of matching principles, we have developed a taxonomy of performance measures. This "performance measure taxonomy" lists about thirty measures of effectiveness which can be used to characterize the performance of the analytic techniques. The same measures of effectiveness can be used to express the performance needs of different decision situations. Matching principles can then be derived by matching the performance of the analytic techniques to the needs of the situation. The dimensions of the performance measure taxonomy include: enhanced logical reasoning, cost, speed, convenience, and facilitated communication.

Together, these three taxonomies constitute a framework for communicating to decision makers matching principles on the proper analytic approaches for decision situations, and comprise a framework in which decision analysts can derive additional matching principles. The major contribution of this report is to present our initial development of this framework. This development is summarized in Volume I and explained in detail in Volume III.

In addition to developing the framework, we have derived a few tentative but important matching generalizations based on the experience of practicing decision analysts. These generalizations reflect the kind of technical judgement that an experienced decision analyst might communicate to a decision maker or to an inexperienced decision analyst. The generalizations presented in this report do not attempt to be exhaustive, much less definitive. To do so would require a formal codification of the entire art of applied decision analysis. Instead, we have selected a few analytic techniques to represent the thousands of options and have used the taxonomic framework to derive some general guidelines on when the techniques should be utilized.

Examples of these guidelines (stated informally here but conforming to the categories developed in the study) are:

1) Generally consider using decision analysis on a single, non-recurring problem only if the "stakes" are more than a hundred thousand dollars, if the options are clearly visualized, and if the decision maker has more than usual difficulty in deciding among them.

2) Use the Delphi method for eliciting group probabilities only if there is a high degree of disparity in the status of group members and if the sources of information available to them are rather similar.

3) Expect to computerize the analysis if there will be more than two occasions to use it, if many runs of the analysis with different inputs will be needed on each occasion, and if a substantial analysis is called for (e.g., because the stakes are high).

4) Use decision analysis in a contingent choice situation (i.e., a decision will need to be made in the future if some specified contingency arises), if it is very likely the contingency will arise, if time to make a decision will then be very short, and if the considerations to be taken into account can be reliably predicted.

In addition to developing the taxonomic framework and deriving tentative matching principles, we have applied these ideas to a variety of actual decision situations. In Volume I, we present a very formal application of the matching principles to a U.S. decision on whether to export high-technology items to the Soviet Bloc. In Volume II, we examine five situations where decision analysis was actually applied by using the matching principles to determine the proper amount of decision analysis and the taxonomic framework (but without a formal matching) to explain the reasoning behind other analytic choices.

Finally, this report suggests some possible directions for future research on matching analytic approaches and

decision situations. This research might develop special-purpose taxonomies that are specifically adapted to certain types of decision makers (e.g., Navy task force commanders, U.S. foreign policy advisors, or product managers in consumer products firms). Alternatively, the research might develop an automatic procedure for applying matching principles in unfolding decision situations.

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PREFACE TO THE REVISED EDITION

The present paper is a technical report on a study conducted over a three-year period, 1974-1977. The study represents a continuing task within the decision analysis research program sponsored by Dr. Martin A. Tolcott, Engineering Psychology Programs, Office of Naval Research.

The Decisions and Designs, Incorporated (DDI) project team consisted of Rex V. Brown, the principal investigator, and Jacob W. Ulvila, under the general direction of Cameron R. Peterson, DDI Technical Director.

Since this project is visualized as a tentative first step in a major undertaking (at its grandest, a codification of the art of applied decision analysis), we would very much appreciate any comments or suggestions which may help produce something like a definitive framework for ourselves and others to work with. If responses are encouraging enough, this material may be adapted at some stage for general publication.

The major revision to our previous report (Brown and Ulvila, 1976), conducted over the last year, is the introduction of five extensive applications of this framework for matching analytic approaches and decision situations to actual decision analysis studies. In addition, we have completely rewritten the main report to improve its clarity. This revision reflects the comments of several reviewers, most notably Drs. Robert Winkler, Michael O'Connor, and Martin Tolcott, the sponsor. Also, the structures of the taxonomies themselves have been revised somewhat as a direct result of the case applications. Finally, the presentation

of the report has been revised. The main section and the appendices are now each in separately bound volumes (Volumes I and III, respectively) and the case studies are bound as a separate volume (Volume II).

1.0 INTRODUCTION

Decision makers and analysts who are in a position to recommend the use of decision analysis are faced with problems of determining what type of analysis, if any, to apply to a given decision situation. Currently, the decision maker or analyst must rely upon his own experience and must make an implicit case-by-case judgment of the appropriate analytic approach for each decision situation. This report is an initial attempt to improve this process by providing a codification of the combined judgments of experienced decision analysts.

1.1 Object and Background

Decision analysis might be defined as "a technology of making up your mind." Central to this technology is the argument that, given a set of reasonable behavior assumptions, any person's optimal decision can be determined from quantified measures of his judgments, attitudes, and perceptions, by maximizing his subjective expected utility. This technology has enjoyed substantial vogue in the literature of management science over the past decade.[1] As with most new technologies, however, the rate at which decision analysis has been applied in practice has been much slower than the rate at which its logical underpinnings have been developed.[2] One reason for this lag is the lack of guidance that exists for identifying the most appropriate decision-analytic techniques to be used in a given situation.

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[1] See, for instance, Raiffa (1968), Schlaiffer (1969), Brown, Kahr, and Peterson (1974), and Handbook for Decision Analysis (1973).

[2] See Brown (1970).

The operational military commander or other decision maker has available to him, in principle, a moderately well developed array of decision-making aids based on decision analytic theory.[3] However, it is by no means always readily apparent to him or, indeed, to his technical advisors when and where he can most advantageously use these tools and how. In theory, these tools can be applied to an almost indefinitely variable degree, to any situation involving choice or inference.

The broad purpose of this project, then is to guide the decision maker and, to a lesser degree, his technical staff, in determining the appropriate use of decision-analytic techniques. As a way of encouraging such guidance, we have developed a taxonomic framework which, we hope, will improve a decision analyst's capability to communicate guidelines on the use of decision analysis to decision makers. This framework takes into account earlier, less extensive attempts to classify or relate situations and analytic approaches.[4] In addition to developing this framework, we have also derived some illustrative practical guidelines. These guidelines are in the form of tentative matching generalizations that should help a decision maker decide whether or not decision analysis is a promising technique to apply in a given situation.

1.2 Terms of Reference

As stated above, an objective of this paper is to encourage and facilitate a codification of the current state of knowledge of applied decision analysis. In order

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[3] See, for example, Section 4 of Brown, et.al. (1974/2).

[4] For example, by Howard (1968), Howard, et.al. (1975 and 1976), MacCrimmon and Taylor (1973), Payne, et.al. (1974), and Von Winterfeldt (1975).

to meet this objective, this paper attempts to suggest a convenient taxonomy for classifying each particular decision situation and a taxonomy of analytical options for addressing those situations, together with such guidance as can be given for an appropriate matching of the two.

Because an attempt to classify completely every conceivable decision-analytic option and every possible decision situation is an unmanageable task (with thousands of taxonomic characteristics for both analytic options and situations), we have restricted our main attention to relatively few major dimensions. These dimensions appear to be sufficient to characterize the important class of matching generalizations that are useful from the standpoint of a decision maker; only secondary consideration is given to developing guidelines for a decision analyst.

This restriction affects both the analytic taxonomy and the situation taxonomy. The scope of the analytic taxonomy is reduced because the serious attention is devoted to the dozens of analytic options that are of interest to the decision maker rather than to the thousands of analytic options that are of interest to the analyst (although our current development of the analytic taxonomy does contain a number of these analyst's options). The content of the situation taxonomy is affected because the most appropriate characterization of a decision situation for specifying the correct options for the decision maker may differ from that appropriate for specifying the correct options for the analyst. For example, the fact that the decision situation calls for formal documentation of the reasons behind a choice may be very relevant to deciding whether or not to use decision analysis at all (a decision maker's option) but almost irrelevant to whether simulation or backwards induction is to be used in the conduct of the decision analysis (an analyst's option).

Primary attention is also restricted to providing universal situation characterizations that allow matching rules to be developed for decision situations in general rather than for a particular class of decision situations, such as those faced by a businessman or those faced by a Navy task force commander. This restriction affects the content of the situation taxonomy. In particular, the situation taxonomy contains situation characterizations that facilitate matching analytic options and situations, rather than ones that make it easy for any particular decision maker to classify his situation. Ultimately, to gain the maximum usefulness from the universal taxonomy, it will be necessary to develop taxonomies that enable situations to be more easily classified. This task is very large because decision makers in different fields, such as business or Navy tactics, tend to classify decision situations in different ways, with the result that a specialized taxonomy may be needed for each field. For example, a businessman may classify decision situations as investment decision situations, marketing decision situations, and so forth. A Navy task force commander, on the other hand, may classify decisions as crisis decisions or wartime decisions. Thus, the specific taxonomy that will serve to relate the decision maker's preferred method of classifying situations to the method used in the universal taxonomy will be different for the businessman and for the task force commander. The development of such specific taxonomies, however, is beyond the scope of the present paper.

In addition to developing the taxonomic framework, the present volume develops a tentative set of matching generalizations in the context of an actual decision situation, a determination of what level of embargo on the sale of computers to the Soviet Bloc should be favored by the U.S. Government.

In addition, the concept of a specific taxonomy is notionally illustrated in the context of a military decision made by the President.

1.3 Research Approach

In constructing a taxonomy of decision-making situations, it is natural to inquire whether principles exist for the construction of taxonomies in general. The most widespread use of taxonomic procedures has been in the biological sciences, and much as been written on appropriate ways to produce classification systems.[5] However, most of the stress in these writings is on the construction of automatic classification procedures. With these procedures, a dissimilarity measure is defined for pairs of objects that are to be classified, and then a clustering method is used to create classes. We do not feel that it is feasible to create such automatic classification procedures for decision-making situations, at least not at this early stage in our approach to the problem, since the similarity or dissimilarity between two decision-making situations involves more subjective judgment than, for example, a comparison of flora or fauna. This similarity, at least at present, is unlikely to be derivable from a numerical formula. Other areas of study have used classification schemes (including human tasks),[6] but there do not appear to be any principles in the literature for the construction of taxonomies that we can apply directly to decision-making situations.

The logic underlying the matching of taxonomies of analytic options and situations is based upon the idea of maximizing the value of the decision analysis performed with due allowance for its cost. The formal principles of this

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[5]See, for example, Sokal and Sneath (1973) or Jardine and Gibson (1971).

[6]See Fleischman (1975).

idea[7] are as yet cumbersome to apply in practice. Accordingly, the approach taken in this paper is rather informal, though implicitly it should be consistent with those principles.

The essential research approach used here was to examine the current state of applied decision analysis as perceived by the authors and others and to seek to codify the implicit taxonomic structures that it contains. The illustrative methodological generalizations used were derived from the wide range of practical experience of analysts at Decisions and Designs, Incorporated. In particular, the generalizations represent the judgments of two analysts (Rex V. Brown and Cameron R. Peterson), each of whom has actively applied decision analysis to a wide range of government and industry problems over the last nine years.

In addition, the situation taxonomy was checked and amplified by examining a large number of practical Naval and other decision situations. Experienced judgment was used to identify and prioritize their important distinguishing characteristics. Similarly, experienced judgment was applied to the classification of analytic options. In both cases, the taxonomies were developed with a view toward creating matching generalizations.

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[7] Watson and Brown (1975/1).

2.0 A TAXONOMIC FRAMEWORK

This project attempts to develop a language for expressing matching generalizations which indicate the analytic approaches that are appropriate for decision situations. Secondly, this project attempts to provide a framework in which such generalizations may be derived. Both of these objectives are advanced through our development of three taxonomies.

First is the "situation taxonomy," which allows a decision maker to classify his decision situation as a "point in situation space." Second is the "analytic taxonomy," which allows decision analysts to classify decision-analytic options in "analysis space." Together, these two taxonomies can facilitate communication between a decision analyst and a decision maker by defining a set of terms that can unambiguously define decision situations and analytic techniques. With this language, decision analysts can state precisely their guidelines for applying the analytic techniques in such a way that the decision maker can understand how they apply to his situation.

The third component of this language is the "performance measure taxonomy," which facilitates the development of matching principles. That is, with the situations defined as "points in situation space" and analyses defined as "points in analytic option space," the performance measures facilitate the process of finding the proper mapping of points in one space onto the other space. This mapping may be visualized analogously to the problem of formulating a regression problem (as explained in the Appendix to this volume). The performance measure taxonomy facilitates the development of matching principles by providing a common

language for expressing the performance needs of decision situations and the performance properties of analytic options.

With these needs and properties stated in the same terms, matching principles can be generated by locating the analytic options that provide the performance properties that are needed in the situation.

2.1 Situation Taxonomy

The situation taxonomy contains dimensions that enable decision makers to define precisely their decision situations. Furthermore, this taxonomy is designed in a manner that facilitates an identification of the appropriate amount and types of decision-analytic techniques to use in a given situation. That is, this taxonomy includes only those situation distinctions, a subset of all possible distinctions, that impact on the performance measures that are important for determining the appropriate amount or type of decision analysis.

Table 2-1 contains a summary of the dimensions in the situation taxonomy. In general, the level of detail in this table indicates the type of question that a decision maker needs to answer in order to classify his situation. Such questions include, for example (under the heading "BASIC SITUATION"):

1. Does the situation require a choice immediately, or will a choice be required only in the event of some future contingency (current/contingent choice)?

2. How many times will you expect to make this same decision (expected number of occurrences)?

1 DECISION SUBSTANCE

11 BASIC SITUATION

111 current/contingent choice
112 expected No. of occurrences
(113 operating/information act)
119 other basic situation

12 OPTIONS

(121 broad/narrow)
122 clear/fuzzy
(123 complexity of decision options)
124 radical/adaptive
125 static/dynamic
129 other options

13 EASE OF DECISION

131 difficulty of choice
132 unfamiliarity
133 key considerations
139 other ease of decision

14 STAKES

141 resources committed
142 cost swing
143 value swing
144 maximum option impact
145 expected irrationality cost
149 other stakes

15 OUTCOME VALUATION

151 difficulty of net valuation
(152 No. of value dimensions)
(153 measurable value?)
(154 natural combinability of values)
(155 timing horizon)
(156 difficulty of component valuation)
159 other outcome valuation

16 OUTCOME UNCERTAINTY

161 No. of uncertainties
162 assessability
163 high/low uncertainty
164 subsequent acts
(165 type of evidence)
166 hindsight monitoring
169 other outcome uncertainty

19 OTHER DECISION SUBSTANCE

2 DECISION PROCESS

21 REACTION TIME

211 minutes
212 hours
213 days
214 months

22 ANALYTIC PROCESSES

221 No. of input sources
222 analytic team
223 constraints on analytic method
224 documentation
225 interest in trying new methods
229 other

23 ORGANIZATIONAL PROCESSES

(231 initiation)
232 responsibility
(233 coordination)
234 justification
235 controversiality
236 performance control
237 rational-actor model
238 risk attitude
239 other organizational processes

24 DECISION MAKER CHARACTERISTICS

241 role in organization
242 personal characteristics
249 other

25 RESOURCES AVAILABLE

251 computational facilities
252 staff
253 decision analysis specialist
254 availability of decision maker
(255 availability and technical sophistication of assessors)
256 dollars available
259 other resources

29 OTHER DECISION PROCESSES

291 negotiation

Table 2-1

SITUATION TAXONOMY – SUMMARY

3. Will your decision result in an action, or are you trying to decide whether or not to seek more information (operating/information act)?

For purposes of classifying the situation in a way that facilitates a matching of the analytic techniques, we have designed these questions as multiple-choice questions; that is, the decision maker chooses from a list of possible responses. For example, for the question on the expected number of occurrences, the decision maker has the following choices of response:

1. Less than one,
2. One,
3. Two,
4. Greater than two.

All of the questions and all of the "multiple choice" possibilities are described in detail in Section A of Volume III.

To streamline the communication and referencing of the specific situation characteristics, we have designed the situation taxonomy around a numerical coding scheme. For example, S112 refers to the question, "How many times do you expect to make this decision?" (see Table 2-1). The final digit of each coded entry of the taxonomy refers to one of the multiple choices. For example, S1123 refers to the answer "Expected number of occurrences = 2" (see Volume III, Section A). The letter "S" is used to distinguish references to the situation taxonomy from references to the other taxonomies.

The items of Table 2-1 that are enclosed in parentheses are questions that are irrelevant for determining the proper

amount of analysis. (They are important for determining the proper type of analysis.) Since a decision maker is initially concerned with how much decision analysis to use, rather than the specific components of the analysis, the parenthetical categories should generally be ignored in a first pass at characterizing a situation.

2.2 Analytic Taxonomy

The analytic taxonomy contains categories for classifying many of the decision-analytic techniques that can be used to solve decision problems. Table 2-2 summarizes the analytic taxonomy as it is presently developed. Although it may be appropriate for a decision maker to be concerned with only the first few analytic choices (those listed under the heading "USER'S OPTIONS"), our present development of the analytic taxonomy is meant to suggest the range of analytic options that an analyst may use as well.

In its final form (which the present effort only suggests), that analytic taxonomy should allow decision analysts to define precisely the possible analytic techniques that may be brought to bear on decision problems. Within such a framework, experienced decision analysts can communicate their guidelines on the appropriate application of decision analysis to less experienced analysts and possibly even to decision makers.

The coding scheme of the analytic taxonomy is similar to that of the situation taxonomy: categories are designed as multiple-choice questions with the last digit signifying the answer. For example, A12 refers to the question, "What amount of money is to be devoted to the analysis?" (dollar amount of analysis); A121 refers to the answer, "Low--less

1 USER'S OPTIONS

11 USE DECISION ANALYSIS AT ALL?

111 intuitive
112 decision analysis
119 other

12 DOLLAR AMOUNT OF ANALYSIS

121 low
122 medium
123 high

13 ROLE OF DECISION ANALYSIS

131 private/public aid
132 prescribed/optional
133 contingent/current analysis
134 optimization/display
135 communication

14 ORGANIZATION

141 analysis source
142 input source
143 "vest-pocket" relation to decision maker?

15 RESOURCES

151 use a decision analysis specialist?
152 use a computer?

2 MODEL APPROACH OPTIONS

21 COMPLEXITY OF ANALYSIS

211 simple
212 moderately complex
213 very complex

22 COMPREHENSIVE/PARTIAL ANALYSIS

221 comprehensive
222 partial

23 DEGREE OF APPROXIMATION

231 low
232 medium
233 high

24 BALANCE OF EFFORT

241 option definition
242 option valuation

3 INPUT STRUCTURE

31 UNCERTAINTY

311 explicit modeling
312 time horizon
313 subsequent acts
314 detail level
315 degree of grouping

32 VALUE

321 comprehensiveness
322 decomposed?
323 aggregation
324 function?

33 SPECIAL FORMS

331 Markov
332 Pareto
333 linear programming

4 INPUT SPECIFICATION

41 DECISION OPTIONS

411 specificity of definition
419 other

42 EVENTS

421 scenarios
422 specific
429 other

43 VALUE CRITERIA

431 units
432 base
433 evaluation date(s) for time stream

44 INDIRECT ASSESSMENTS

441 conditioned assessment model?
442 Bayesian updating?
443 decomposed assessment model?
444 regression?
449 other

45 ELICITATION TECHNIQUE

451 for discrete probabilities
452 for continuous variables
453 for values
454 use group elicitation ?

5 OUTPUT

51 SPECIFICATION

511 preferred decision
512 single value for each option
513 value distributions
519 other

52 DISPLAY FORMAT

521 graphic
522 computer
529 other

53 ANALYTIC DEVICES

531 use simulation
539 other analytic devices

6 MODEL MANAGEMENT

61 MODEL DYNAMICS

611 combining
612 pooling
613 sequential modeling
614 decision option scanning
615 input iteration

62 CONTINGENT ANALYSIS INPUT SEQUENCE

621 values
622 priors
623 likelihood
624 data

Table 2-2

ANALYTIC TAXONOMY – SUMMARY

than $15,000" (see Table 2-2). Any particular complete analysis will be characterized along many dimensions of the taxonomy. The letter "A" is used to distinguish references to the analytic taxonomy from references to the other taxonomies.

The categories of the analytic taxonomy are presently only partially developed. In this development, we have attempted to cover, at a broad level, as represented by the level of detail in Table 2-2, the wide range of analytic choices that a decision analyst will typically make during the course of an analysis. However, this broad framework is not developed uniformly in the complete description of the taxonomy (Section B of Volume III). In particular, only a few categories have been developed to a very fine level of detail. For example, category A53 is developed to a fine level of detail as follows:

A53 Analytic devices
    A531 Use simulations?
        A5310 No
        A5311 Yes
            A53111 Use Step-through?
                A531110 No
                A531111 Yes
            A53112 Number of trails
                A531121 Few
                A531122 Many

while category A12 is developed to a course level of detail, as follows:

A12 Dollar amount of analysis
    A121 Low
    A122 Medium
    A123 High

This uneven development was done purposefully to suggest the form of analytic taxonomy that might ultimately be developed without attempting such a development. We hope that this presentation might stimulate other decision analysts to develop other categories to finer levels and thus "fill out" the taxonomy.

2.3 Performance Measure Taxonomy

The performance measure taxonomy consists of categories that can be useful to decision analysts who seek to develop matching principles that state the analytic approaches best suited for different decision situations. An analyst can use this taxonomy to specify the performance properties of the various analytic techniques and to specify the performance needs of different decision situations. Then, by searching these specifications, an analyst can identify the various analytic techniques that meet the needs of different decision situations and thus match the analytic techniques to the situations.

Table 2-3 summarizes the present development of the performance measure taxonomy. This taxonomy is used differently from the other two. To use this taxonomy, one does not answer a series of multiple-choice questions. Rather, one prioritizes the categories to specify the needs of a decision situation, and one rates the degree to which each category is met to specify the properties of an analytic technique. For example, a particular decision situation may be characterized as needing:

- High performance on the categories of fast calculation (P213), inexpensive input assignment (P222), and good communication (P321).

1 QUALITY OF DECISION

11 LOGIC OF CHOICE

111 conceptual completeness
112 effective disaggregation
113 sound predictions
114 good overall logic
115 scope
119 other

12 QUALITY OF INPUT

121 good data gathering
122 good management of staff/ expertise
123 posing meaningful questions
124 good overall input quality
129 other

2 TIME AND COST

21 ELAPSED TIME

211 short elapsed modeling
212 fast input assignment
213 fast calculation
214 fast interpretation
215 short overall net elapsed time
219 other

22 COSTS

221 inexpensive analysis
222 inexpensive input assignment
223 inexpensive calculation
224 inexpensive overall
229 other

3 OTHER CONSIDERATIONS

31 ACTIVITY PRECEDING CHOICE PROCESSES

311 good environment monitoring
312 good decision identification
313 good option generation
314 good pre-analysis of anticipated decisions
319 other

32 ACTIVITY FOLLOWING CHOICE PROCESSES

321 good decision communication
322 good hindsight evaluation
323 effective implementation
329 other

33 ORGANIZATIONAL AND OTHER NON-"CHOICE SPECIFIC" IMPACTS

331 improved information
332 improved command, control, and communication
333 improved body of applied precepts
339 other

Table 2-3

PERFORMANCE MEASURE TAXONOMY – SUMMARY

- Some performance on the categories of sound predictions (P113) and good environmental monitoring (P311).

- Little or no performance on other categories.

Likewise a particular analytic technique may be identified as having the properties of:

- Providing very effective disaggregation (P112) and high conceptual completeness (P111).

- Providing some posing of meaningful questions (P123) and improving the utilization of staff expertise (P122).

- Performing poorly on short elapsed modeling time (P211) and inexpensive analysis (P221).

References to the performance measure taxonomy are distinguished from references to the other taxonomies by the letter "P." The categories of the performance measure taxonomy are explained in detail in Section C of Volume III.

3.0 MATCHING HIGHLIGHTS

In Section 2, we explained the concept of using taxonomies as a language for expressing matching principles and as a means for deriving such principles, and we described briefly the specific situation taxonomy, analytic taxonomy, and performance measure taxonomy that we have developed. In this section, we illustrate the way that the taxonomies can be used by experienced decision analysts to derive matching principles and the way that the taxonomies can be used to communicate matching principles to decision makers and inexperienced analysts.

In Section 3.1, we shall use the taxonomies to derive some guidelines for determining whether or not decision analysis is a promising technique to use in particular decision situations. Throughout this effort, our emphasis will be on ensuring that our guidelines can be communicated usefully to decision makers, so that the _decision makers_ can determine whether decision analysis is useful for their decision problems. Because this is our initial attempt at generating such matching principles, we do not argue that they are ready for adoption as they stand as tenets of recommended decision analytic practice. Rather, these matching principles are presented as hypotheses that can later be refined by ourselves and others and as guidelines that might be of some immediate use to decision makers and inexperienced decision analysts.

In Section 3.2 we explain how our derivation of matching principles might be extended to consider a matching of specific analytic techniques to decision situations. In doing so, our main goal is to illustrate how experienced

analysts might eventually codify guidelines that could be used by inexperienced analysts (or even decision makers) to decide upon the proper mix of analytic techniques to apply to any given decision situation. In addition, it is our hope that the specific generalizations we present are found useful by analysts and that these generalizations will stimulate some debate among experienced analysts which will eventually produce more definitive guidelines for the applied practice of decision analysis.

3.1 Amount of Decision Analysis

In this section, we restrict our attention to the question that should be of primary concern to a decision maker who is contemplating engaging in a decision analysis effort, "How much decision analysis, if any, is right for my situation?" As we explained above, we derive matching generalizations in the framework of the taxonomies by a two-step process. First, the properties of decision analysis are described in terms of the performance measure taxonomy. Second, the performance needs of the various categories in the situation taxonomy are identified and matching generalizations are derived by identifying the situation categories that need the performance that decision analysis can provide. Throughout this section, references to the situation taxonomy are preceded by the letter "S" and references to the performance measure taxonomy are preceded by the letter "P." Readers who desire more detailed explanations of the terms of these taxonomies are referred to Sections A and C of Volume III.

3.1.1 Performance characteristics of decision analysis - The first step in deriving matching principles for identifying situations in which a decision analysis is recommended is to

rate the properties of decision analysis on each performance measure. In all of the discussion below, the performance of decision analysis is stated relative to the performance of conventional decision-making procedures as exemplified by intuitive or informal decision-making procedures. In particular, the statements do not refer to the performance of decision analysis relative to other quantitative approaches, such as operations research or management science techniques. In addition, the performance characterization below is stated in terms of broad generalizations. As with all generalizations, there are exceptions to these rules. Finally, these generalizations represent highly personal judgments of the authors though they are grounded in substantial experience.

The following performance measure generalizations are presented in the order in which the measures appear in Table 2-3, "Performance Measure Taxonomy--Summary," and the reader should not attach any significance to the order of presentation.

Decision analysis performs well in most of the categories in the first performance area, the quality of the decision (P1). Within this performance area, decision analysis generally performs well in both categories, logic of choice (P11) and quality of input (P12). Within the logic of choice category, which addresses the extent to which decisions are in logical agreement with the available information, decision analysis performs well on most subcategories. In particular, increasing the amount of decision analysis that is applied to a problem generally increases:

- the extent to which the total decision problem is disaggregated into more manageable subproblems (P112); and

Decision analysis does not perform well, in general, in the second performance area, time and cost (P2). In the first category in this performance area, elapsed time (P21), decision analysis does not perform well on any of the "first-pass" time sub-categories, that is, timeliness categories that relate to the first time that a decision model is built. In particular, increasing the amount of decision analysis that is applied to a problem generally increases:

- the time required initially to structure a model of the problem (P2111);

- the time required initially to assign values to the input parameters (P2121);

- the time required initially to perform the calculations needed to recommend a decision (P2131); and

- the time required initially to interpret the output of the analysis (P2141).

All of this results in an overall increase in first-pass modeling time (P2151).

Additional uses of the same analysis will, however, generally permit decisions to be made more quickly than when decision analysis is not used. In particular, increasing the amount of decision analysis that is applied to a problem generally reduces

- the time necessary to assign values to the input parameters (P2122),

- o the quality of the predictions that are made using the available data (P113).

Increasing the amount of decision analysis does not, however, have a clear impact on the conceptual completeness of the problem's consideration (P111). On one hand, a decision analysis tends to increase a decision maker's understanding of his problem, but, on the other hand, using decision analysis can often lead a decision maker to omit important considerations. Weighing these factors, we conclude that, on balance, the overall logic of the decision is improved (P114) as an increasing function of the amount of decision analysis applied.

Within the quality of input category (P12), which addresses the extent to which complete, accurate, and timely data and judgments are obtained, decision analysis performs well in all sub-categories. In particular, increasing the amount of decision analysis that is applied to a problem generally improves:

- o the extent to which complete, accurate, and timely data are obtained (P121);

- o the extent to which the available staff and expertise are managed to produce timely and accurate data processing (P122); and

- o the extent to which meaningful questions are posed to request the appropriate data and judgments (P123).

The combined effect of this is to increase the overall quality of the inputs (P124).

- the time necessary to calculate a recommended decision (P2132), and

- the time necessary to interpret the output of the analysis (P2142)

for additional passes of the same model. Thus the overall time for additional passes (P2152) decreases as the amount of decision analysis increases. (The effect of the amount of decision analysis on the modeling time for additional passes (P2112) is not clear.)

The net overall elapsed time (P2153), including both the first and additional passes, generally increases as the amount of decision analysis increases.

In the cost category (P22), increasing the amount of decision analysis always raises the cost of the analysis effort. This effect carries through all sub-categories. In particular, increasing the amount of decision analysis that is applied to a problem generally increases:

- the cost of the analysis (P221);

- the cost involved in assigning inputs to the model (P222); and

- the cost involved in calculating a model's output (P223).

This relationship holds for both the first pass and additional passes. We emphasize that we use the term cost in the context of the cost of an analysis; these costs do not consider the gains that might accrue because of better

outcomes obtained as a result of doing the analysis. (The tradeoff between the cost of an analysis and its potential benefits is one of the considerations that must be weighed to make matching generalizations.)

In the third performance area, other considerations (P3), the effects of decision analysis cannot be generalized for most subcategories. Increasing the amount of decision analysis that is applied to a problem does not have a clearly generalizable effect on a decision maker's ability to:

- monitor his decision environment for indications that a problem exists (P311);
- recognize when a decision must be made (P312);
- generate alternative decision options (P313);
- think through and analyze anticipated future decisions in advance (P314);
- implement his choice (P323);
- recall, correlate, and present data that is relevant to the decision (P331); or
- command and control his organization (P332).

However, increasing the amount of decision analysis will generally improve a decision maker's ability to:

- communicate his decision and any supporting arguments for it (P321);
- evaluate, after-the-fact, the quality of the decision (P322); and

- develop doctrine (P333).

Using this performance characterization, the amount of decision analysis indicated in a situation can, in principle, be determined by a direct assessment of the relative importance of the performance measures. That is, to the extent that a decision situation requires the performance characteristics that decision analysis can supply more than those that it cannot supply, more decision analysis is indicated. However, it is typically very difficult for a decision maker to make such an assessment of the relative importance of the performance characteristics directly. Usually, it is easier for him to characterize his decision situation in terms of the situation taxonomy. Thus, in order for the taxonomy framework to provide a decision maker with useful guidelines for identifying the situation in which decision analysis is most useful, it should state its matching principles in terms of the situation taxonomy rather than the performance measure taxonomy.

3.1.2 Situations favoring the use of decision analysis - The section above illustrates the first step that an analyst would take in deriving matching principles for identifying the proper amount of decision analysis for different decision situations, characterizing decision analysis in terms of the performance measure taxonomy. This section illustrates how an analyst can complete the derivation of matching principles by characterizing the needs of the various situational categories in the situation taxonomy and then matching these needs with the performance properties of decision analysis.[1]

[1] The matching task is conceptually analogous to the formulation of a regression problem. This analogy is presented in the Appendix.

The result of this matching exercise is a set of guidelines that allow a decision maker to classify his situation in terms of the situation taxonomy and then, using the matching principles, determine the proper amount of decision analysis for the situation. (Recall that our comparison is always between using decision analysis and using no formal analysis techniques; we are not comparing decision analysis with other formal analysis techniques.)

Statement of matching principles - The results of this matching exercise, guidelines for determining the proper amount of decision analysis, are summarized in Table 3-1. Unless otherwise noted, the situation characteristics that are indicated as supporting the use of decision analysis (marked by an "X") also support the use of increasing amounts of analysis the more the actual situation exhibits the situational characteristic. The reader should bear in mind that the following statements are guidelines that should be considered as a whole rather than individually. That is, to use these guidelines, a decision maker must weight the extent that his situation favors decision analysis against the extent that it argues against decision analysis to arrive at an overall determination of whether decision analysis is promising for the situation.

As shown in Table 3-1, the key situation characteristics that argue for a large amount of decision analysis are:

- o Clearly and unambiguously defined options (as might be characteristic of a situation where a decision maker must select one of five bidding contractors) (S1221).

		SITUATION CHARACTERISTICS	Amount of Decision Analysis			
			None	Lo – < $15k	Med – $15k–$50k	Hi – >$50k
Decision Substance	Basic Situation	S1111 Current Choice				X
		S1124 More than Two Expected No. of Occurrences				X
	Options	S1221 Clear Options				☒
	Ease of Decision	S1312 Difficult Choice				☒
		S1334 Key Consideration Choice				☒
	Stakes	S1441 Maximum Option Impact < $100K	X			
		S1442 Maximum Option Impact $100K–$5M		X		
		S1443 Maximum Option Impact $5M–$10M			X	
		S1444 Maximum Option Impact > $10M				☒
	Outcome Valuation	S1512 Very Difficult Net Valuation				X
	Outcome Uncertainty	S1621 Indeterminable Uncertainties				X
Decision Process	Reaction Time	S214 Months of Reaction Time				X
	Analytic Processes	S2215 Several Input Sources for Both Preferences and Substantive Inputs				☒
	Organizational Processes	2343 Both Pre and Post Justification				☒
		2372 Rational Actor Model is a Good Approx.				X
	Decision Maker Characteristics	S24213 D.M. Has Much Familiarity with Decision Analysis				☒
	Resources Available	S2512 Many Computational Facilities Available				X
		S2522 Strong Staff Available				X
		S2542 Much Decision Maker Availability				X
		S2563 Greater than $50,000 Available				X

☐ Indicates the key situation dimensions

Table 3-1

MATCHING HIGHLIGHTS – AMOUNT OF DECISION ANALYSIS

- A difficult choice, where a decision maker is perplexed about what to do and there is a high "cost of confusion" (S1313).

- Choice, rather than option generation or information gathering, being the key determinant of a good decision (S1334).

- Large stakes, where the maximum option impact (the expected difference in outcome between the best and worst plausible decision) is greater than $10 million (S1444).

- Several sources of inputs, both preference inputs and substantive inputs, should be considered (S2215).

- The decision must be justified both before and after it is made (S2343).

- The decision maker is very familiar with decision analysis techniques (S24212).

Other situation characteristics that indicate decision analysis, but which are not as important as those listed above, include:

- A choice that will result in an immediate action (current choice) rather than in an action that will be taken in the event of the occurrence of a future contingency (S1111).

- A choice that will recur (S1124).

- A difficult valuation (e.g., where many intangible value criteria are important) (S1512).

- Uncertainties that are difficult to assess (S1621).

- Months of reaction time, a decision is not needed until months after the problem arises (S214).

- Organizational processes that resemble a "rational actor model" (S2372). (The "rational actor model" hypothesizes a unitary decision maker who wishes to make his decisions on the basis of reasoned judgment.)

- A computer facility that is readily available (S2512).

- A strong staff that is readily available to work on an analysis (S2522).

- A decision maker who can spend a lot of time interacting with the analysis (S2542).

- A large budget that can be devoted to the analysis (S2563).

To use these generalizations, a decision maker needs to classify his situation along each of the situation dimensions mentioned above and then judge the extent to which his situation coincides with that indicated above. Section 4.1.1 below illustrates how a decision maker might use these guidelines in the context of an actual decision problem, and Volume II presents five additional applications.

Derivation of matching principles - The discussion above explains the results of the matching exercise, matching generalizations that can be used by a decision maker. The discussion below explains how these generalizations were derived by experienced decision analysts using the taxonomies to specify the needs of the situations and then matching the performance properties of decision analysis to the situational needs. The discussion presented here is brief and covers only the most important situation characteristics, which are mentioned in Table 3-1. A more complete presentation, which discusses all of the categories in the situation taxonomy, is given in Section D of Volume III. (The discussion below is presented in the same order as the discussion above.)

Key situations - Decision analysis can improve conceptual completeness (P111) most when the choice options are clearly specified (S1221).

Decision analysis can provide the greatest improvement in the decision quality (P1) for difficult choices (S1313). When choice is difficult, informal decision processes leave much room for improvement, which can be filled by using decision analysis.

Decision analysis can generally improve choice logic (P11). Thus, decision analysis is indicated in situations in which choice is the key consideration (S1334). [In addition, since decision analysis does not offer any particular advantage in generating options (P313), or gathering information (P331), decision analysis is not indicated if these are the key determinants of a good decision (S1331, S1332).]

The stakes involved in the decision (S14) are the single most important situation classification for

determining the appropriate amount of decision analysis. In general, the cost of the analysis (P22) becomes less important as the stakes increase. Thus, decision analysis is indicated in high-stakes situations. As a rough guideline, we suggest that the maximum option impact, the difference in expected value between the best decision and the worst plausible decision, should be on the order of $100,000 (S1442) to justify the expense of even a small (less than $15,000) decision analysis. Of course, decision analysis is more strongly indicated if the maximum option impact is greater than this threshold.

Conventional, intuitive decision practice has difficulty organizing inputs that come from a variety of sources. Decision analysis, however, provides a method for organizing a diverse set of inputs. In particular, decision analysis can improve the quality of both input (P12) and choice logic (P11) when multiple input sources (S2215) exist. Input quality is especially improved through the effective management of staff and expertise (P122), and choice logic is especially improved through the effective disaggregation of the decision problem (P112) that decision analysis promotes.

Decision analysis can provide a vehicle for good decision communication (P321), which is required in situations in which decision justification is needed (S2343).

In a situation in which the decision maker is familiar with decision analysis (S24212), the analysis can provide its greatest benefits, especially the effective implementation of a decision (S323), the effective management of staff expertise (P122), and good overall decision logic (P114).

<u>Secondary situations</u> - Current choice situations (S1111) favor the use of decision analysis because these situations guarantee that the analysis could be used. Since decision analysis is a tool to aid in decision making, its value as an aid is reduced in contingent situations (S1112) in which it is uncertain that the decision will ever occur.

A decision that is expected to recur (S1124) supports the use of decision analysis because the cost (P22) per analysis is reduced. The amount of advantage gained by recurrence, of course, depends upon both the expected frequency of recurrence and the similarity of the recurring situations because the similarity determines the amount of modification needed before the analysis can be used again. The expected number of occurrences is, in general, closely related to the current/contingent question (S111) explained above, and these two dimensions should be considered simultaneously. For instance, a current decision that will occur only once should be considered the same as a contingent decision that has a 50% chance of occurring twice. Both of these situations have an expected occurrence rate of one.

Decision analysis can improve choice logic (P11) in situations in which valuation is difficult (S1512).

Decision analysis can improve choice logic (P11) in situations in which uncertainties are difficult to assess (S1621), that is, in situations in which it is difficult to identify the appropriate probability distribution to represent an uncertain quantity.

More time is required to perform a decision analysis than to use informal, intuitive decision-making techniques (P21). Thus, situations with long reaction times (S214) support the use of decision analysis.

Since decision analysis assumes a "rational actor model," a situation that is a good approximation of this model (S2372) supports the use of decision analysis.

Good computational facilities tend, in general, to reduce the cost of analysis (P221). Thus, decision analysis is supported where good computation facilities are readily available (S2512).

A strong staff (S2522) is most likely to perform a decision analysis correctly and thus improve the overall logic of the choice (P114).

If a decision maker is unavailable during the analysis time, the improvement in choice logic (P11) and input quality (P12) provided by decision analysis is reduced. Thus, decision analysis is supported when the decision maker is available (S2542).

Since decision analyses are fairly costly (P22), the analysis budget that is available can constrain the size of the decision analysis. Naturally, a large analysis is supported by a large budget (S2563).

3.2 Examples of Types of Analysis

In this section, we extend the concept of developing matching principles, beyond the issue of how much analysis, to consider the specific decision analysis techniques to use in given decision situations. The guidelines presented here are meant to illustrate how experienced decision analysts might eventually use the taxonomies to codify matching principles that could guide inexperienced analysts. In addition, the specific guidelines presented here are meant

to be useful in their present form and are also meant to stimulate debate among experienced analysts that will eventually produce more definitive guidelines for the applied practice of decision analysis. We do not expect these matching principles to be guidelines that a decision maker can use on his own, without the additional guidance of a decision analyst.

Table 3-2 summarizes the matching generalization that we have derived for twenty-two specific analytic choices. Section E of Volume III contains a detailed description of the derivations of all of these generalizations, and Section 4.1.2 of this volume presents a case illustration of how these generalizations might be applied. The sections below present three examples chosen from Volume III; they are:

1) situations favoring the use of a contingent choice analysis;
2) situations favoring the use of a computer to perform the analysis; and
3) situations favoring the use of the Delphi assessment technique.

3.2.1 Contingent analysis (A1331)[2] - An analysis performed in advance of a decision that is expected to arise in the future.

Performance characteristics - A contingent choice requires a large amount of time initially (P2151).[3] However, it provides a fast response on subsequent uses (P2152). In addition, in a situation that is characterized by a short reaction time (S211),[4] performing a contingency

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[2]Analysis options are described in Section B of Volume III.

[3]Performance measures are described in Section C of Volume III.

[4]Situation dimensions are described in Section A of Volume III.

	DECISION SUBSTANCE: Basic Situation			Options		Ease of Decision				Stakes		Outcome Valuation				Outcome Uncertainty			DECISION PROCESS: Reaction Time		Analytic Process		Organizational Process			Decision Maker Characteristics	Resources Available									OTHER
SITUATION CHARACTERISTICS	S1111 CURRENT CHOICE	S1112 CONTINGENT CHOICE	S1124 MORE THAN TWO EXPECTED NO OF OCCURRENCES	S1221 CLEAR OPTION	S1222 FUZZY OPTIONS	S1331 EASY CHOICE	S1313 DIFFICULT CHOICE	S1333 KEY CONSIDERATION: INFERENCE	S1334 KEY CONSIDERATION: CHOICE	S1442 MAXIMUM OPTION IMPACT MODEST	S1444 MAXIMUM OPTION IMPACT HIGH	S1510 EASY NET VALUATION	S1512 VERY DIFFICULT NET VALUATION	S1551 EARLY TIMING	S1553 LATE TIMING	S1621 UNCERTAINTIES THAT ARE DIFFICULT TO ASSESS	S1623 UNCERTAINTIES THAT ARE EASY TO ASSESS	S1643 IMPORTANT SUBSEQUENT ACTS	S211 MINUTES OF REACTION TIME	S214 MONTHS OF REACTION TIME	S2213 SEVERAL PREFERENCE SOURCES	S214 SEVERAL SUBSTANTIVE SOURCES	S2343 BOTH PRE AND POST JUSTIFICATION	S2352 VERY CONTROVERSIAL DECISION	S2372 RATIONAL ACTOR MODEL IS GOOD APPROX.	S24212 DECISION MAKER HAS MUCH FAMILIARITY WITH DECISION ANALYSIS	S2512 POWERFUL COMPUTER READILY AVAILABLE	S2520 NO STAFF AVAILABLE	S2522 STRONG STAFF AVAILABLE	S2540 DECISION MAKER NOT AVAILABLE	S2542 DECISION MAKER VERY AVAILABLE	S25511 LOW ASSESSOR AVAILABILITY	S25512 HIGH ASSESSOR AVAILABILITY	S2561 LESS THAN $15,000 AVAILABLE	S2563 GREATER THAN $50,000 AVAILABLE	OTHER
A123 LARGE DOLLAR AMOUNT OF DECISION ANALYSIS	x		x	[X]			[X]		[X]		[X]		x			x				x	x	x	[X]		x	[X]	x		x		x				x	
A1331 CONTINGENT CHOICE		[X]	[X]	x							[X]								[X]		x															PREDICTABLE ANALYSIS
A1341 OPTIMIZATION *																			x																	COMPREHENSIVE ANALYSIS (A221)
A1521 USE A COMPUTER *			[X]								[X]									x							[X]		x							CLEAR, COMPLEX STRUCTURE (A213), HIGH INPUT ITERATION (A61533)
A213 VERY COMPLEX ANALYSIS *							x				x				x			x		x	x	x	x	x		.x	x		[X]	x			x		x	
A2221 PARTIAL ANALYSIS– INFERENCE ONLY					x			x		x		x				x																				
A231 APPROXIMATE ANALYSIS						x				x																			x			x				MANUAL COMPUTATION
A3121 SHORT TIME HORIZON													x	[X]			x															x		x		LOW UNCERTAINTY (S1631) LOW COMPLEXITY (A211)
A3132 SUBSEQUENT ACTS AS EVENTS																		x																		INFORMATION & SUBSEQUENT ANALYSIS DIFFICULT TO MODEL
A3222 DECOMPOSE VALUES *										x	x		x							x	x			x			x						x			NATURE OF VALUE
A32311 ADJUSTED VALUE INDEX																							x	x												OPTIMIZING MODE (A1341)
A32411 LINEAR VALUE FUNCTION *																							x					x				x				
A3311 MARKOV MODEL								x				x					x																			SPECIAL STRUCTURE
A3321 PARETO MODEL																																				NEGOTIATION (S291)
A3331 LINEAR PROGRAMMING MODEL				[X]								x															x		x	x						LARGE OPTION VECTOR (S1236) CERTAIN (S1630), LINEAR, STRUCTURED
A4322 FLOATING VALUE BASE *										x		[X]																	x							NO JUSTIFICATION NEEDED (S2340)
A4413 MANY CONDITIONING TIERS								x		x	x					[X]				x		x					x		x							EACH TIER ACCOUNTS FOR 10%–20% OF TOTAL VARIANCE
A4421 BAYESIAN PROBABILITY MODEL								x																					x							SPECIAL PERCEPTUAL STRUCTURE
A4531 REFERENCE GAMBLE ELICITATION																							x						[X]				[X]			RISK AVERSE OR RISK SEEKING DECISION MAKER (S2381)
A45412 DELPHI ASSESSMENT																						[X]														STATUS HETEROGENEOUS, DATA HOMOGENEOUS
A53111 SIMULATION *											x																									COMPLEX STRUCTURE (A213), CONDITIONED ASSESSMENT (A4413)
A531111 STEP THROUGH SIMULATION															x	x							x						[X]				x			

x Indicates a situation/analytic match

☐ Indicates a key matching characteristic

* Taxonomic dimensions also relate to the application presented in Section 4.1.2

Table 3-2

MATCHING SUMMARY – TYPE OF ANALYSIS

analysis in advance can improve the choice logic (P11), the input quality (P12), and the decision maker's ability to control his organization (P332).

<u>Situations favoring contingent analysis</u> - The most important situation considerations for determining whether to perform a contingent analysis include the number of occurrences (S112), the stakes (S144), and the reaction time (S21).

In general, contingent choice analysis is indicated in situations in which its cost (P22) is justified by either a large number of occurrences (S1124) or by large stakes (S1444). As a rule of thumb, a contingent analysis should not be performed unless the expected number of occurrences is at least one (P1122) (for example, occurring once with certainty or occurring twice with a 50% probability). It is also necessary to consider the similarity as well as the number of occurrences. The more similar the situations are, the more the contingent analysis is justified. (Again, as a rule of thumb, we consider three similar recurrences to be roughly equivalent to a single identical recurrence.) For a good pre-analysis (P314), it is critically important that the actual decision is predictable, that is, involves the same considerations that are modelled.

As a guideline, the expected option impact over the total number of occurrences should exceed $10 million (S1444) to justify the cost of a contingent analysis. Brown, et.al. (1975) present an illustration of this guideline in a Navy task force commander's decision situation.

In a situation with a short reaction time (S211), a pre-analysis of contingencies can improve decision quality (P1) by providing a logical framework that considers all available data.

In addition, a contingent analysis is supported, but less strongly, by a situation with clear options (S1221) and several value sources (S2213). Clear options (S1221) allow a contingent analysis to provide a good pre-analysis of the anticipated decision (P314). Clear options also enhance predictability (see above). Contingent choice analyses can improve command, control, and communication (P332) in situations that require several value sources to be considered (S2213).

3.2.2 Use of computer (A1521) - Performance characteristics - A computerized analysis is generally time-consuming and costly to set up (P2131 and P2231) but is fast and inexpensive to run (P2132 and P2232). However, when an analysis is complex, a computer may not increase the initial time or cost.

Situations favoring the use of a computer - These include a recurring situation (S1124) or a situation with large stakes (S1444). Since a computer offers faster and less expensive performance on subsequent passes, its use is supported by a large expected number of occurrences (S1124). Large stakes argue for the use of a computer for two reasons. First, large stakes justify the large costs needed for a computerized analysis. Second, a situation with large stakes generally involves a complex analysis. In this case, a computerized analysis may not be more expensive than a manual analysis.

The following situations support the use of a computer, but less strongly than those mentioned above.

A computer analysis requires at least several days of anticipatory reaction time (S213). However, since a

computerized analysis runs quickly, only minutes of execution reaction time (S211) are needed.

Some staff support (S2521) is needed to program a computerized analysis.

The costs (P22) and time (P21) of a computerized analysis are not significantly worse than the alternative of a non-computerized analysis if the situation has clear, complex options (S1221 and S1236); many assessable uncertainties (S1613 and S1623); and many measurable values (S1523 and S1532).

A computer is also recommended in conjunction with a complex analysis (A213) and with simulation (A5311).

3.2.3 <u>The Delphi Technique (A45412)</u> - A group elicitation technique for probabilities.

<u>Performance characteristics</u> - The Delphi Technique involves pooling opinions of several probability assessors while allowing only limited interaction among them.

<u>Situations favoring the use of the Delphi Technique</u> - These include only those with several uncertainty sources (S2214).

The Delphi Technique limits interaction among assessors and provides the assessors with anonymity. Thus, the Delphi Technique removes inhibition and allows better use of staff expertise (P122) in cases where the status of the assessors is heterogeneous. However, if data is heterogeneous, then the Delphi Technique reduces input quality (P12) by inhibiting useful interactions. (See Fischer [1975] for a further evaluation of the Delphi Technique.)

4.0 MODE OF USE

In Section 3.1 above, we presented matching principles that could be used by decision makers to recognize promising situations in which to use decision analysis. In Section 3.2, we extended our presentation of matching principles to include those that might be used by inexperienced decision analysts to recognize the most promising specific analytic techniques. At their current state of development, these matching principles, expressed in the language of the situation taxonomy, are too complex to be applied routinely in unfolding decision situations.

What is ultimately needed to make the taxonomies and matching principles fully operational is a procedure for progressively applying the taxonomy so that it will operate like a succession of progressively finer screens. With such a procedure, the decision maker would need to answer only a few routine questions, perhaps related to the size of the stakes involved, the time available to make a decision, the clarity of the choices, and the complexity of the outcomes, to identify those situations that should be seriously considered for decision analysis. For those situations, the decision maker would answer a second level of more sharply focused questions to make a definitive decision on whether to use decision analysis and, if so, what role the analysis will serve. After resolving these issues, the decision maker together with a decision analyst would answer a series of even more sharply focused questions to determine the detailed planning of the analysis. The screening would continue until the exact analytic options are identified or until informal technical judgment is sufficient to designate the type of analysis.

Some of the decision analysts who reviewed an earlier version of this report have expressed the opinion that such a procedure is an unrealistic and undesirable goal--unrealistic because the number of important situation characteristics and analytic techniques is so large, undesirable because such a procedure could be dangerously misleading if it were used uncritically. We feel that these points are well taken; however, we do not want to pre-judge the results that future research efforts may produce. At this time, though, any such procedure for applying the matching principles remains a distant goal.

Section 4.1 below, presents a formalized application of the matching principles, as they are currently developed, to an actual case study. Section 4.2 illustrates the form that an ultimate procedure for applying the matching principles might take and also presents a suggestion for an alternative type of taxonomy that might be more useful for certain specific types of decision makers.

4.1 Formalized Application of Existing Matching Principles

The following sections illustrate, in a formalized case application, how the matching principles of Section 3.0 might be used by a decision maker and an analyst. Section 4.1.1 illustrates how a decision maker might use the guidelines presented in Section 3.1 to determine the appropriate amount of decision analysis, and Section 4.1.2 illustrates how a decision analyst, in conjunction with the decision maker, might use the guidelines presented in Section 3.2 to choose the specific analytic techniques for the same situation. This presentation, especially the discussion of the type of analysis, follows a much more formalized structured approach than do the case presentations in Volume II.

4.1.1 Amount of decision analysis to use on export control decision - In the summer of 1973, a senior staff member of the President's Council of International Economic Policy (CIEP) had to make a recommendation to the President on the level of embargo for computers sold to the Soviet Bloc. If approved by the President, in consultation with the Departments of State and Defense, this recommendation would provide the basis for the U.S. position on COCOM embargo policy. COCOM, an international coordinating committee representing the major western powers and Japan, is charged with controlling the export of computers and other strategic items to communist countries. The essential decision by COCOM was to specify where, in terms of computing power, to set the "easy access line" for computers.

Six weeks before his recommendation was due, the CIEP staffer was faced with a very large array of reports from experts on the complex issues involved in the decision. These issues included the impact of the decision on military threat, U.S. computer sales, the attitude of COCOM allies, and other economic and political considerations. Although the staffer had some sense of where the "easy access line" should be set, he felt uneasy about his ability to properly digest and interpret the complex mass of data available to him within the limited time available.

The first question, then, was how much, if any, decision analysis the staffer should have done, and, secondly, what specific form the decision analysis should have taken.

Table 4-1 indicates how the matching highlights shown on Table 3-1 might be used, informally, to conclude that a substantial amount of decision analysis should be used. It can be seen that all but three of the seventeen

SITUATION CHARACTERISTICS

		Code	Situation Characteristic	Amount of Decision Analysis (None / Lo – < \$15k / Med – \$15k–\$50k / Hi – >\$50k)	Export Control Characterization
Decision Substance	Basic Situation	S1111	Current Choice	Hi – X	+
		S1124	More than Two Expected No. of Occurrences	Hi – X	+
	Options	S1221	Clear Options	Hi – $\boxed{X}$	+
	Ease of Decision	S1313	Difficult Choice	Hi – $\boxed{X}$	+
		S1334	Key Consideration Choice	Hi – $\boxed{X}$	–
	Stakes	S1441	Maximum Option Impact < \$100K	None – X	
		S1442	Maximum Option Impact \$100K–\$5M	Lo – X	
		S1443	Maximum Option Impact \$5M–\$10M	Med – X	
		S1444	Maximum Option Impact > \$10M	Hi – $\boxed{X}$	+
	Outcome Valuation	S1512	Very Difficult Net Valuation	Hi – X	+
	Outcome Uncertainty	S1621	Uncertainties that are Difficult to to Assess	Hi – X	–
Decision Process	Reaction Time	S214	Months of Reaction Time	Hi – X	+
	Analytic Processes	S2215	Several Input Sources for Both Preferences and Substantive Inputs	Hi – $\boxed{X}$	+
	Organizational Processes	2343	Both Pre and Post Justification	Hi – X	+
		2372	Rational Actor Model is Good Approx.	Hi – $\boxed{X}$	+
	Decision Maker Characteristics	S24212	D.M. Has Much Familiarity with Decision Analysis	Hi – $\boxed{X}$	+
	Resources Available	S2512	Many Computational Facilities Available	Hi – X	–
		S2522	Strong Staff Available	Hi – X	+
		S2542	Much Decision Maker Availability	Hi – X	+
		S2563	Greater than \$50,000 Available	Hi – X	+

$\boxed{X}$ Indicates the key situation dimensions

\+ Indicates characteristic is present

– Indicates characteristic is not present

Table 4-1

EXPORT CONTROL EXAMPLE – AMOUNT OF DECISION ANALYSIS

situation characteristics favoring a large amount of decision analysis are present in this case, including all but one of seven key characteristics.

Specifically, proceeding from left to right, we see that the choice was a current one, and that the decision situation was expected to recur (the issue is expected to come up for re-examination every two years or so). The options were somewhat clear, in the sense that the theoretically rich and complex option space could be reduced to six specific alternatives without gross oversimplification. The choice was, however, not particularly difficult in that the decision maker was rather sure that the right choice lay between three of the six options. The decision maker saw his key problem as choosing from among perceived options (rather than making predictions or determining what the options are, for instance). All measures of stakes were very high; the maximum option impact was on the order of hundreds of millions of federal budget dollars. The net valuation of possible outcomes was very difficult (trade-offs of economic, political and military considerations were required), but the uncertainties were not unusually difficult to assess. The reaction time was on the order of a couple of months. There were several different sources of input for the various types of uncertainty and prediction, all of which were different from the sources of value judgment. The decision required justification in a formal report to the President and in verbal presentations to representatiaves of industry and government agencies both before and after the decision was to be made. The decision processes of government for this decision are reasonably "rational" (in that reasoned argument is a large part of the persuasion process). The decision maker was highly familiar with decision analysis (having taught the subject at a major university). Computational facilities and staff skills were

more than adequate. The decision maker was able to spend large amounts of time participating in the analysis on a regular basis. However, the budget available was quite modest, on the order of $30,000.

At this stage of development, we do not propose any formal decision rule for determining routinely the proper level of decision analysis to use. Rather, this determination must be made informally by weighing the factors for and against decision analysis. In this case, all but one of the key situational characteristics favoring decision analysis are present (only "difficult choice" is absent). Additionally, all but two of the other ten situational characteristics favoring decision analysis are present (only "difficult to assess probabilities" and "large analysis budget" are missing). Thus, we would recommend a large analysis, on the order of $50,000 for this situation. Regardless of this recommendation, though, only $30,000 was available to perform the analysis. Thus, this constraint ultimately determined the size of the analysis. (Additional considerations indicated that a medium-sized analysis could also be useful since it was not the case that a choice had to be made between a large analysis and none at all.)[1]

4.1.2 <u>Type of decision analysis to use on the export control decision</u> - The following discussion illustrates how a decision analyst, in conjunction with the decision maker, could choose the proper analytic techniques, from among those listed on Table 3-2, for this situation. To follow this discussion, the reader should also refer to Table 3-2.

---

[1]Watson and Brown (1975/2) presents an attempt to establish the value of this particular analysis, after the fact.

The discussion below treats these decisions in a much more formalized way than the same types of considerations are treated for the five case studies in Volume II.

The analysis emphasized the display of the considerations and reasoning involved in the decision rather than the optimization of the model to determine the "best" decision (A1342) because the scope of the analysis, at the client's request, was not comprehensive (A2222); certain political dimensions of value, such as impact on detente were deliberately excluded from the analysis. The display of the decision's impact on those dimensions of value that were explicitly modeled (economic, military, and so forth), however, permitted an evaluation of how large the excluded political considerations would need to be in order to change the preferred option.

A computer was used (A1521) because the decision was expected to recur about every two years (S1124), the stakes were high (S1444), and many input iterations (A61533) were expected. The large number of input iterations, modifications of the value and probability inputs within the same model structure, was indicated because this decision was very controversial (S2352).

The complexity of the analysis was low (A211); in particular, only one probability distribution was modeled (on one dimension of value--military threat), primarily because probability assessors were not very available (S2551). In addition, low complexity was indicated because this analysis budget was modest (S2562).

Subsequent acts were not explicitly modeled (A3130) because they did not have enough impact on the possible outcomes (S1641) to justify any explicit modeling.

On the other hand, value was decomposed extensively (A3222) into its four major dimensions (U.S. computer sales, allied goodwill, military threat, and other) and one dimension, military threat, was decomposed into sixteen specific categories. Reasons for this decomposition were that the sources of preference judgment were different (S2213) and that the decision was controversial (S2352), especially regarding trade-offs among value dimensions (for example, determining how much improvement in computer sales would compensate for a deteriorating military threat).

The decompositions were all linear (A32411) because of a need for both pre- and post-decision justifications (S2343). That is, linear decompositions are much easier to communicate in order to justify the decision.

The value scales used a "floating zero base" (A4322), which evaluate all outcomes relative to some base outcome, because the technical problems of valuation of each dimension were not very difficult (S1510) and because experienced staff (S2522) were available to handle the greater technical subtlety involved.

In performing the calculations, simulation was not needed (A5310) because the model structure was not complex (A211).

4.2 Two Useful Extensions of this Study: A Sequential Procedure and Specific Taxonomies

As previously mentioned, the taxonomies and matching principles as they are currently developed are not in a form that can be applied routinely in unfolding decision situations. Two possibilities for future development may improve upon

this situation. First, the matching principles might be arranged into a sequential procedure of progressively finer screens. Second, the categories in the situation taxonomy might be redefined in "specific taxonomies" that are easier for particular decision makers to use.

Section 4.2.1 below explains the concept of a procedure of successively finer screens, and Section 4.2.2 explains the concept of specific taxonomies. These ideas are presented as ideas for future research, not as products of that research.

4.2.1 A sequential matching procedure - Decision makers and decision analysts may encounter substantial elicitation problems if they attempt to use the matching principles in the manner illustrated above. A decision situation, as it unfolds, is typically difficult to classify along any situational dimension. Furthermore, hundreds of such situational classifications are potentially relevant to the identification of the best analytic techniques. However, for any particular analytic choice (for example, the choice of whether to use decision analysis at all), only some of the situation dimensions are relevant and a subset of these may even be sufficient to make the choice. For example, the fact that a decision involves very small stakes may be sufficient to indicate that nothing should be spent on a decision analysis effort. As another example, in the export control decision above, the very large stakes (S1444) and the modest analysis budget (S2562) were sufficient situation characteristics to determine the proper amount of decision analysis.

Because it is often the case that only a few of the potentially relevant situational characterizations are actually needed, a procedure for progressively applying the

situation taxonomy and matching principles would enhance their usefulness. With such a procedure, a decision maker would need to answer only a few routine questions to identify whether his decision situation is a promising one for decision analysis. If it is, then he would answer a second level of more sharply focused questions to make a definitive decision on whether to use decision analysis and, if so, what role the analysis should serve. After resolving these issues, the decision maker, together with a decision analyst, would answer a series of even more sharply focused questions to determine the detailed planning of the analysis.

Figure 4-1 shows notionally, in a flowchart, the form that such a procedure might take, but it does not represent a considered proposal for such a procedure. In this flowchart, questions that determine the situational distinctions that are most important for determining the amount of analysis are asked first and questions that determine the specific details of the best analysis techniques to use are asked later and only if they are appropriate, as indicated by earlier answers. In this way, an elicitation sequence progresses, with the answer to each situational question either indicating an analytic choice or calling up a new question, in such a manner that only the minimum number of situation characteristics necessary to determine the best analysis techniques need to be specified. A complete flowchart of this form would represent, in effect, a manual of applied decision analysis.

Although such a complete flowchart could be very useful to decision makers and inexperienced decision analysts if it were developed and used properly, we, as well as some of the reviewers of our original report, feel that such a development may be an unrealistic goal. First, the

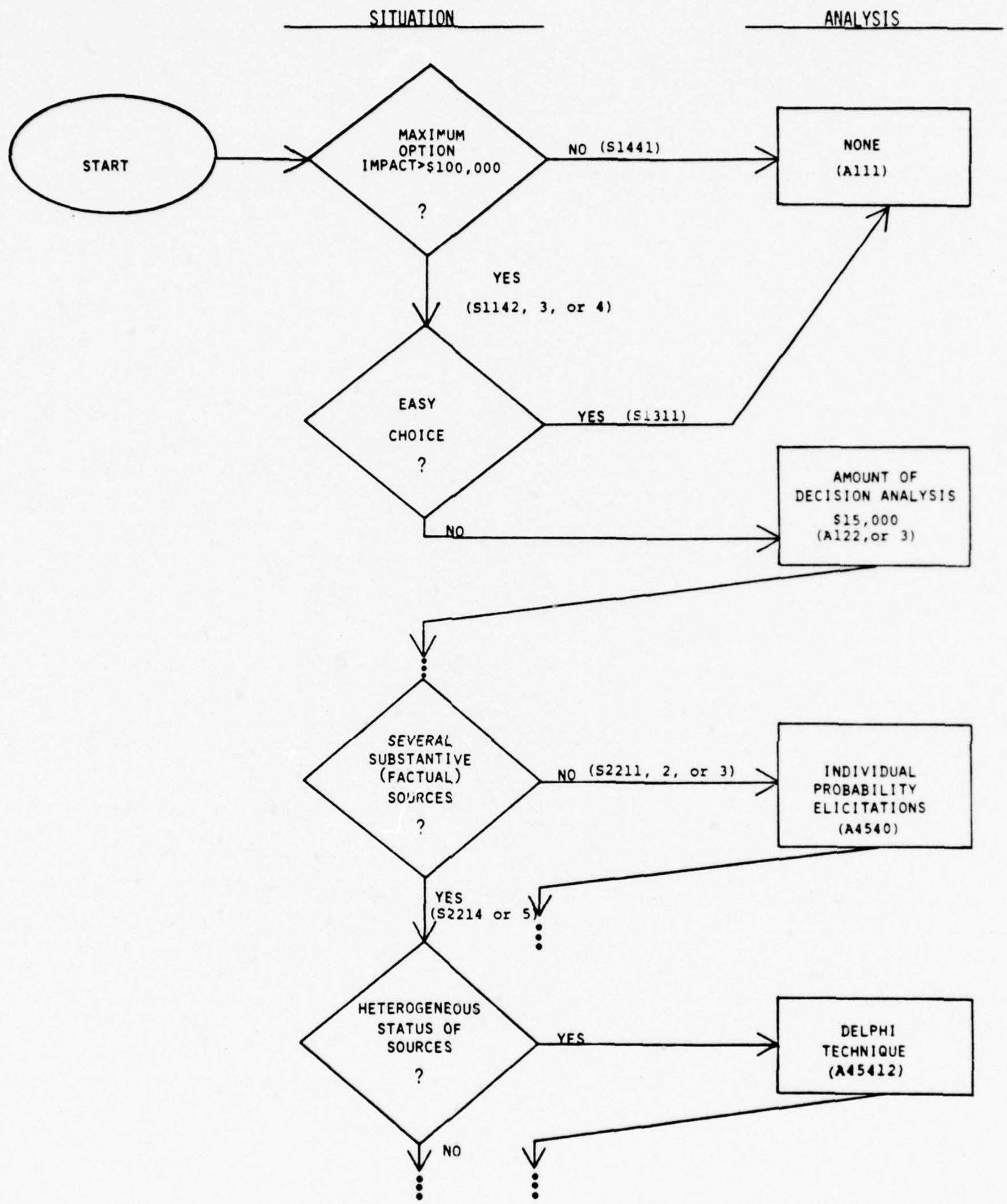

Figure 4-1

ELICITATION SEQUENCE

numbers of potentially relevant situational characteristics and analytic techniques are so large that the task may be unmanageable. Second, it is quite possible that the interactions of the effects of different situational characteristics are sufficiently complex that very little gain in elicitation is possible. That is, so many situation characteristics are needed to determine the best analysis that the questions cannot be ordered in a way that reduces the elicitation burden. Third, unless very definitive matching principles are obtained, the flowchart procedure is vulnerable to misuse by decision makers who blindly follow the recommendation of some automatic procedure. At this time, we do not feel that a search for a definitive procedure is a very promising research area. Thus, although we do not want to pre-judge the results that future research might produce, at this time we are not very optimistic about the chances of producing a definitive procedure for applying matching principles.

4.2.2 Specific situation taxonomies - The situation taxonomy was designed to allow a decision maker to classify his decision situation. However, the characteristics that we identified in our situation taxonomy, which are relevant characteristics for determining the proper amount and type of analysis, are often difficult to use. It is desirable, therefore to seek out mediating situational characteristics that enable an easy characterization to serve as a surrogate for a relevant one. We feel that the best way to provide for easy situational characterizations is to develop specific taxonomies which are specific to particular fields of decision making and are based upon concepts that are familiar in those fields. These specific taxonomies would contrast with the universal taxonomy presented above which is not specific to a particular area of decision making.

Figure 4-2 illustrates notionally the manner in which a situation might be classified along both the President's (acting as the National Command Authority, NCA) specific situation taxonomy and the universal situation taxonomy to determine the appropriate analysis techniques. The decision to commit U.S. forces to neutralize an island from which a foreign power is launching attacks against one of our allies (which could precipitate a global war) might be classified as a "crisis" situation on the specific taxonomy.[2] This characterization is associated with the universal dimensions of "multiple value sources," "controversial," and "high stakes." Through matching generalizations, the situation characterization indicates that a substantial scale of decision analysis, requiring explicit disaggregation of value, is indicated. In conjunction with other specific or universal descriptions of the situation, this matching indicates specific analytic choices, a step-through simulation model and linear decomposed valuation.

Table 4-2 illustrates another example of how a specific taxonomy matching might be developed. In this case, a decision analyst's specific taxonomy is applied to a situation in which he is attempting to decide whether business decisions or federal government decisions are more promising for applying his methodologies.

Table 4-2 indicates that government decisions are more frequently associated with the universal situation characteristics favoring decision analysis than are business decisions. Therefore, Table 4-2 suggests that, as a general rule (modified of course by particular circumstances--other

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[2] This illustration was developed for the "ONRODA Warfare Scenario," Payne and Rowney (1975).

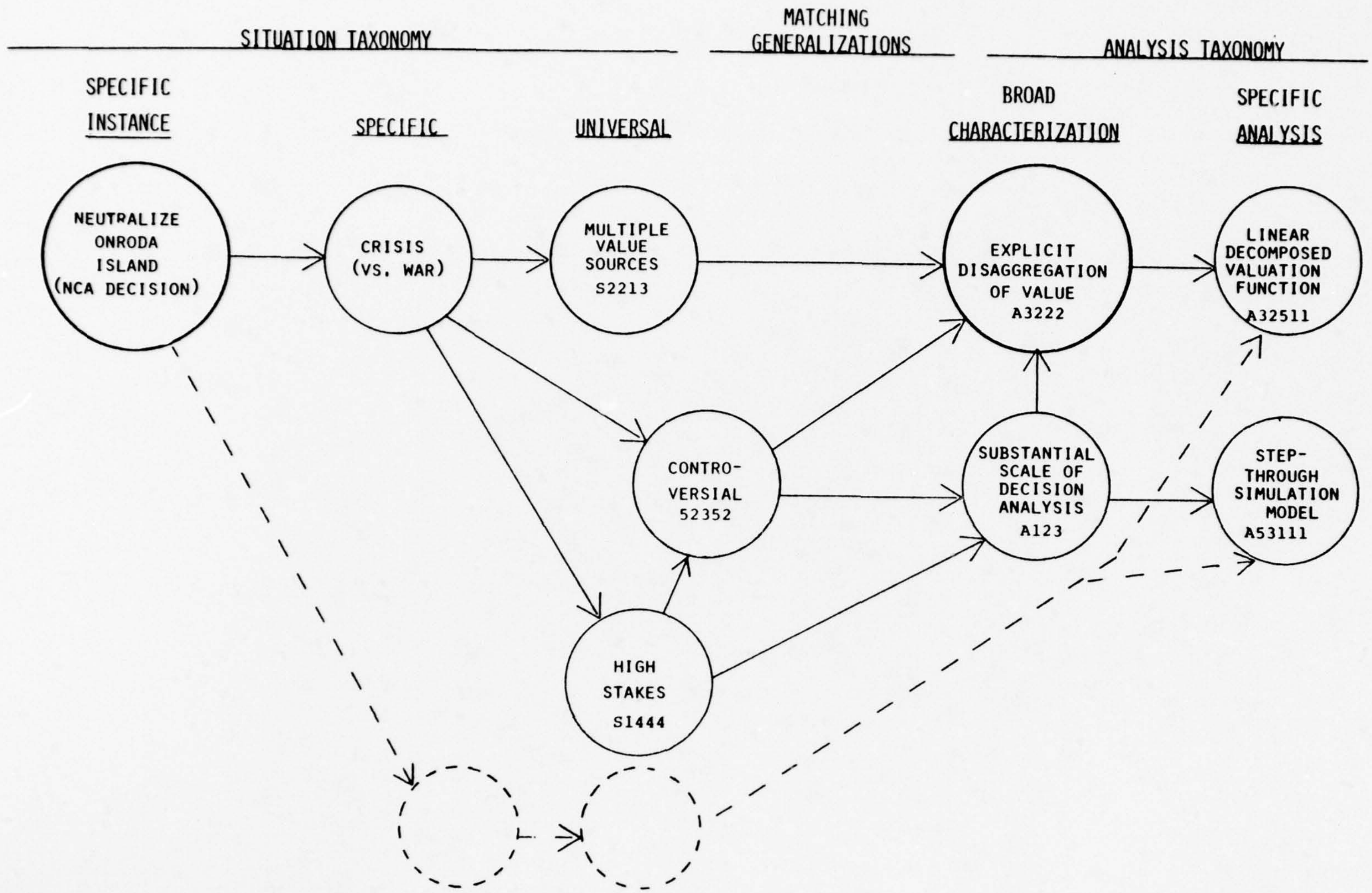

Figure 4-2
ILLUSTRATIVE USE OF TAXONOMY MATCHING

Universal Taxonomy Characteristics Favoring DA	Specific Taxonomy Characteristics: Government	Specific Taxonomy Characteristics: Business
High expected number of occurrences (S1124)		X
Difficult choice (S1312)	X	
High stakes (S14)	X	
Difficult net valuation (S1512)	X	
Several sources for both substantive and and preference inputs (S2215)	X	
Controversial (S2352)	X	
Need for post-decision justification (S2343)	X	

Specific matching conclusion: government decisions tend to favor the use of decision analysis more than business decisions do.

Table 4-2

APPLICATION OF SPECIFIC TAXONOMY

specific or universal situation characteristics), government decisions favor decision analysis more than business decisions do.

The specific taxonomy examples presented above are intended only to present the idea and to point the direction for future research.[3] These specific taxonomies themselves are certainly not developed to the stage where they are useful.

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[3] In addition, a start has been made in Sections 1, 2, and 6 of Brown, et.al., (1974/2) on developing a specific taxonomy for naval tactical situations.

5.0 CONCLUSIONS

5.1 Implications of Work Completed

It is important for the reader not to confuse the ultimate goal of this project with the modest and tentative beginning which this report represents. The ultimate goal of this project is to provide decision makers with the ability to identify the formal decision analysis techniques that are best for any decision situation. One way to achieve this goal is to provide guidance in the form of matching principles which relate analytic techniques to decision situations. This report presents a conceptual framework in which such guidance can be communicated and derived. In addition, it presents some notional ideas as to what that guidance might be.

Even when the situation and analysis taxonomies of this report are completed to a fine level of detail, their main contribution will be as a means for decision analysts to communicate matching principles to decision makers. Together with the performance measure taxonomy, these taxonomies may also provide a framework in which decision analysts can derive matching principles. We do not expect the taxonomies themselves, however, to make substantial contributions to the development of such matching principles.

The specific matching principles presented in this paper are neither exhaustive nor definitive. Rather, they represent the recommendations of a few experienced decision analysts at Decisions and Designs, Incorporated. These recommendations are presented both as useful guidelines for decision makers and as examples of how decision analysts might use the taxonomies to derive matching principles. We hope that, in this latter capacity, the specific matching

principles put forth in this paper will stimulate some methodological inquiry that will result in more definitive statements about the art of applied decision analysis.

5.2 Future Research

Since this report is only a tentative first step toward the codification of applied decision analysis practice, we are well aware that much remains to be done to arrive at a definitive taxonomic framework. In the process of developing this tentative beginning, we have identified a number of promising avenues for future research. These include:

1. Refining and enriching the taxonomies and the matching principles of this report to reflect a more thorough investigation of the same issues and to reflect a wider range of decision analysis experience (involving organizations other than Decisions and Designs, Inc.).

2. Developing specific taxonomies and matching generalizations for particular purposes. Following the idea presented in Section 4.2.2, these taxonomies would attempt to classify situations using summary characteristics that are familiar to certain specific kinds of decision makers. Some discussions of these types of characterizations for Navy task force commanders are presented in Appendix A of Payne, et.al. (1974) and Sections 1, 2, and 6 of Brown, Hoblitzell, Peterson, and Ulvila (1974).

3. Extending the matching principles presented in this report to the point of proposing specific decision rules which go beyond a simple listing of favoring situational characteristics.

4. Developing a sequential procedure for matching the proper analytic techniques to decision situations, for example, by proposing and testing in practice specific procedures to help a decision maker or an inexperienced analyst evaluate candidate decision situations for decision analysis (e.g., developing a procedure along the lines of the flowchart in Figure 4-1.)

5. Developing interactive computer programs to implement a filtering procedure developed along the lines of item 4 above.

6. Developing a framework similar to the one presented in this paper directed at the problem of matching decision situations with information needs (rather than analytic techniques). Such an inquiry, or a specific version that is specific to Naval tactics, might be a valuable adjunct to the development of the information component of a tactical flag command center (TFCC) of the type currently under consideration in the U.S. Navy.

APPENDIX

CONCEPTUAL FRAMEWORK FOR MATCHING

This appendix presents a conceptual framework for the matching task. Specifically, an analogy is drawn between the matching task and the task of formulating a regression problem. This analogy is presented only as a conceptualization of the matching problem and does not imply that the matching task can actually be formulated in a mathematical representation.

Formally, we can visualize the matching task as formulating a regression or other estimating function of the form:

$$\underline{A} = f\ (\ \underline{P}\ ) = \Phi\ (\ \underline{S}\ )$$

where

$\underline{A}$ is the appropriate values (choices) of the analytic option vector,

$\underline{P}$ is the vector of all relevant performance requirements for a given situation,

$\underline{S}$ is the (much larger) vector of all relevant situation characteristics, and

f and Φ are the appropriate mapping functions.

In general, $\underline{P}$ and $\underline{S}$ are unavailable because the size of the vector is too great for practicality because the elements in the vector are not accurately measured. Typically, what we have available are $\underline{P}'$ and $\underline{S}'$, more manageable sets of estimated performance requirements and situation characteristics, such as those proposed in our performance measure and situation taxonomies.

As in regular regression practice, we are faced with the problem of implicitly or explicitly formulating an estimate of $\underline{A}$, $\hat{\underline{A}}$, of the form:

$$\hat{\underline{A}} = \theta (\underline{P}', \underline{S}')$$

where 0 is an estimate of the appropriate mapping function that minimizes the expected error, $E (\underline{A} - \hat{\underline{A}})$, subject to the cost of measuring and implementing θ, $\underline{P}'$. $\underline{S}'$.

The practical counterpart of this approach is that our matching generalizations may incorporate both performance measures and situation characteristics.

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